THE RELATION OF WEATHER FACTORS TO THE YIELD OF WINTER WHEAT IN BOX ELDER COUNTY, UTAH

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ABSTRACT

A multiple linear regression equation is developed which relates the yield of winter wheat to "effective" precipitation during certain months of a crop year. Antecedent precipitation and other weather factors are investigated to determine their effect on yields.

1. INTRODUCTION

The relation of weather factors to crop yields is being studied now more than ever before. The economist is interested in learning more about these relationships so that future economic conditions can be foretold more accurately. Agronomists are concerned with such studies so that, among other things, wiser recommendations for crop planting can be made for various areas. The farmer, the geographer, the crop insurance worker, and others also benefit as our knowledge of weather-crop relationships increases. In this paper an attempt is made to correlate the yield of one of the important dryland crops in Utah, winter wheat, with certain weather factors.

It is a well-known fact that wheat is the most important grain crop in the world. Wheat is adapted to a wide range of climate and soils, but it is grown principally in moderately dry temperate climates having an average annual precipitation of less than 30 inches [4]. The highest average yields are usually obtained in regions with an annual precipitation of 25 to 30 inches [3]; but in Utah the principal dryland farming areas receive less than 15 inches, on the average [9].

There are several weather factors affecting the growth and yield of wheat. Zink [11], in his study of the weather elements important to wheat growth and yield near Nephi, Utah, found the highest correlations were with evaporation, length of drought periods, and rainfall. He also found that correlations with mean temperatures were low, but were higher with maximum and minimum readings. Zink concluded that the best statistical results are obtained by using plant growth stages. However in the present study which is confined to Box Elder County, Utah, little if any phenological data for winter wheat were available, and it was necessary to use weather data for specific calendar periods. Also, there were no evaporation records available for use in this study.

Some of the factors that other investigators have believed to be important are: the amount, distribution, reliability, and effectiveness of rainfall; length of growing season; the amount of sunlight and soil moisture; snowfall; snow cover; and the frequency and duration of very low or very high temperatures [1, 11].

The principal climatic factor limiting the yield of winter wheat over western United States is insufficient precipitation. In the growth of this crop there appears to be at least two critical periods in which adequate soil moisture is essential to the production of maximum yields. One of these is the period during heading, blooming, and filling. Another critical period is the time of planting [8].

Most of the winter wheat in Utah is of the hard red class and is grown principally on "summer fallow" ground. This crop is usually planted in September and harvested in July. Diseases such as rust, scab, mildew, and leaf spots; leaching of plant food from the soil; excessive growth and lodging; and difficulties in planting, harvesting, and caring for the crop are not as much of a problem in Utah as in more humid climates [6].

Although this particular study is confined to Box Elder County, which ranks first in the production of small grains in Utah, it is believed that the results would be applicable to other dryland winter wheat areas of western United States. Box Elder County, in northwestern Utah, comprises an area of 5,600 square miles, with about 90,000 acres planted to dryland winter wheat [7]. Most of the cultivated crops are produced in the southeastern portion of the county. The northern and western sections are used principally for grazing.

2. PROCEDURE AND RESULTS OF STUDY

Winter wheat yield data were obtained from the office of the Agricultural Marketing Service, U.S. Department of Agriculture, Salt Lake City, Utah; temperature and precipitation data were taken from *Climatological Data*, Utah (monthly and annual issues) published by U.S. Weather Bureau.

The first step was to analyse the yield data for time

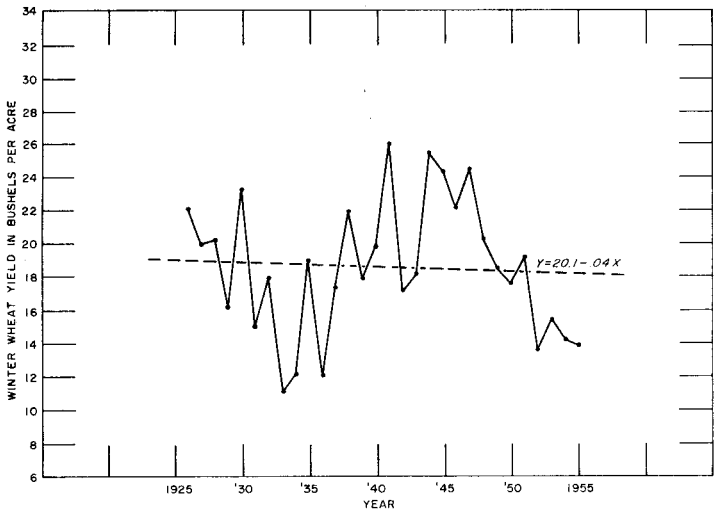

FIGURE 1.—Winter wheat yields, in bushels per acre, for Box Elder County, Utah, plotted against years for the period 1926–55. The regression line is dashed.

trends during the period under consideration (1926–1955) to determine the effect of improved cultural practices, etc., on average yields. According to a study made in 1951 by the U.S. Department of Agriculture [10], the average yield of *all* wheat in the United States showed a pronounced increase during the period 1939–1948, compared to the eight decades prior to 1939. In the Western States, an early peak was reached in 1915, with the yield dropping markedly in 1917 and remaining relatively low through 1940.

In Box Elder County there is no evidence of a marked time trend in the winter wheat yield data from 1926 through 1955. A linear regression line fitted to yields shows a slight decrease of about 1 bushel per acre during this period, but a "t" test indicates this change is not significant at the 5 percent level. The regression line and a plot of annual yields versus years are shown in figure 1.

Precipitation records for ten weather stations in and near Box Elder County were tested for consistency for the period 1926–1955, by the double-mass analysis technique [2]. Of the ten stations, seven were found to have compatible records that could be used without any adjustment of the data. The correlations between seasonal precipitation (July of one year through June of the following year) at five of the stations (Grace, Idaho; Brigham City, Corinne, Richmond, and Riverdale, Utah) and the annual wheat yields in bushels per acre for Box Elder County were computed. From examination of these correlations and some analyses by multiple regression, Grace and Riverdale were dropped and precipitation at Brigham City was assigned a weight of 0.50, Corinne 0.30, and Richmond 0.20.

The effective monthly precipitation for the period under consideration was then computed. Effective precipitation is the sum of the precipitation values times the respective station weights. This procedure is identical with the one outlined by Linsley, et al. [2], except effective precipitation in this study is correlated with wheat yield rather than water-year runoff.

TABLE 1.—*Predicted and actual yields of wheat in bushels per acre for Box Elder County, Utah, for 1956 and 1957*

Year	Predicted yield	Actual yield	Predicted −actual yield
1956	20.3	17.1	3.2
1957	21.4	19.3	2.1

Since it was known that for the production of maximum winter wheat yields, adequate soil moisture is necessary at the time of planting and during heading, blooming, and filling, precipitation data during the months of September, October, May, and June were used in this study. A three-variable correlation was computed, using as parameters the following: Y=annual yield of dryland winter wheat in bushels per acre; X_1=effective precipitation in inches for September plus October; and X_2=effective precipitation for May plus June. The relationship of these variables is shown by the scatter diagram of figure 2. The sloping lines on this chart are least squares lines for annual winter wheat yield. The regression equation was determined to be:

$$Y=8.8+1.67\,X_1+1.85\,X_2,$$

where Y=estimated annual yield of winter wheat. The coefficient of multiple correlation R for this set of data is 0.735. R measures the degree of linear association between the estimated and observed values of the dependent variable [5], in this case between the estimated and observed average wheat yields. R^2, that part of the total sum of squares which has been explained by linear regression, is 0.540. In other words, about 54 percent of the variation in wheat yield can be accounted for by variations in X_1 and X_2.

The average forecast error for the sample was 2.3 bushels per acre. Yields were forecast too low 17 times, with an average error of 2.2 bu. per acre, and were forecast too high 13 times with an average error of 2.5 bu. per acre. The standard error of estimate was computed as 2.73.

Average wheat yields for Box Elder County, Utah, are not available prior to 1926. 30 years of record was considered a minimum amount of data for a study such as this; hence, only 2 years (1956 and 1957) of test data were available. A comparison of the predicted and actual wheat yields for those years is shown in table 1.

3. OTHER FACTORS INVESTIGATED

Winter kill of wheat is occasionally a problem in Utah [9] and, obviously, this reduces the average yield in some years. The amount of damage to winter wheat as a result of low temperatures depends, in part, on the actual values of the minimum temperatures observed and whether there is a snow cover on the ground when the low temperatures

occur. However, the introduction of these variables into the regression equation did not improve the results significantly. (The addition of the lowest winter temperatures at Corinne, Utah, accounted for only an additional 2 percent in the variation of winter wheat yields.)

As was mentioned above, most of the winter wheat in Box Elder County is planted on "summer fallow" ground. One might expect that the inclusion of an antecedent precipitation variable in the regression equation would improve the predictability of winter wheat. However, the addition of the following variables did not change the results significantly: (1) The sum of the effective precipitation amounts for April, May and June of the previous crop year. (2) Effective precipitation for the entire previous crop year.

This is not to say that summer fallowing is not effective. It may be that enough moisture is added to the soil, even in the driest years, so that the amount of precipitation during the fallow year is seldom the principal limiting factor in the production of maximum yields, or possibly the measure of "fallow year" precipitation used does not adequately express the important factor of soil moisture at planting time.

The relationship of other weather factors to the yield of winter wheat was investigated. Some of these were: (1) The lowest monthly winter mean temperature at Corinne, Utah. (2) The mean temperature for the months of April, May, June, and July at Corinne. (3) The effective precipitation for the entire crop year, August through July. (4) Maximum temperature for the months of May and June at Corinne.

4. CONCLUSIONS

Dryland winter wheat yield in Box Elder County, Utah, is related principally to the amount and seasonal distribution of precipitation.

The results of this study indicate the importance of adequate moisture in September, October, May, and June. If sufficient soil moisture is available during those months, there is an excellent chance of an above average yield in the crop year.

The addition of other variables to the regression equation, such as effective precipitation during the previous crop year, winter minimum temperatures, and effective precipitation for the current crop year, did not improve the results significantly.

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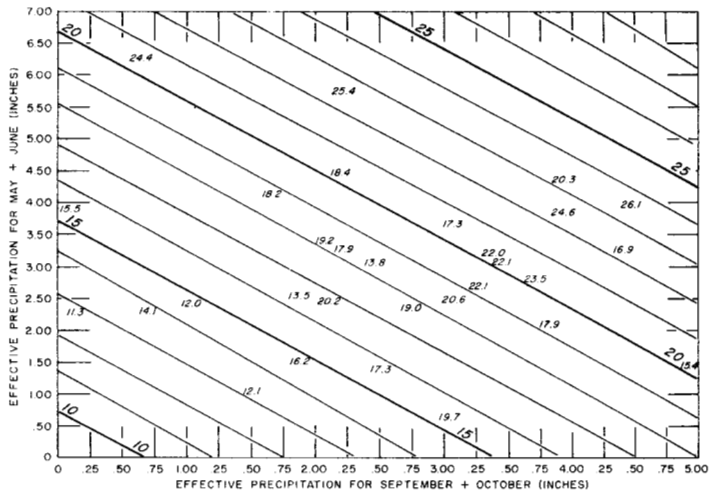

FIGURE 2.—Joint relationship between September plus October precipitation and May plus June precipitation and yield of winter wheat, in bushels per acre, Box Elder County, Utah.

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